CLAIMS

1. An optical information recording medium for recording information by a plurality of record mark lengths, wherein the shortest mark length is at most 0.5 μm, and a crystal state is an unrecorded or erased state and an amorphous state is a recorded state, which has, on a substrate, at least a phase change recording layer, wherein erasing of information is made by recrystallization which substantially proceeds by crystal growth from a boundary between a peripheral crystal portion and an amorphous portion or a melt portion.

2. The optical information recording medium according to Claim 1, wherein the phase change recording layer is made of a thin film comprising Ge, Sb and Te as main components.

3. The optical information recording medium according to Claim 1, wherein the phase change recording layer is made of a thin film comprising, as a main component, a $M_y(Sb_xTe_{1-x})_{1-y}$ alloy ($0.6 \leqq x \leqq 0.9$, $0 < y \leqq 0.2$, M is at least one of Ga, Zn, Ge, Sn, In, Si, Cu, Au, Ag, Al, Pd, Pt, Pb, Cr, Co, O, S, Se, Ta, Nb and V).

4. An optical information recording medium for recording information by a plurality of record mark lengths, wherein the shortest mark length is at most 0.5 μm, and a crystal state is an unrecorded or erased state and an amorphous state is a recorded state, which has, on a substrate, a phase change recording layer which is made

of a thin film comprising Ge, Sb and Te as main components, wherein said medium will be crystallized when the recording layer is continuously irradiated at a constant linear velocity with a recording laser beam having a writing power Pw sufficient to melt the recording layer, and an amorphous mark will be formed when the recording layer is irradiated at a constant linear velocity with a recording laser beam having a writing power Pw sufficient to melt the recording layer, and then the recording laser beam is cut off.

5. The optical information recording medium according to any one of Claims 1 to 4, wherein when recording of signals is carried out by a plurality of record mark lengths of which the shortest mark length is at most 0.5 μm, the recording is made under the following condition:

$$M_1/M_0 \geqq 0.9$$

wherein M_0 represents a modulation of signals retrieved immediately after the recording, and M_1 represents a modulation of signals retrieved after the recording medium is kept for 1,000 hours under a condition of 80°C and 80% relative humidity after the recording.

6. The optical information recording medium according to any one of Claims 1 to 4, wherein when recording of random signals of EFM plus modulation system is carried out by a plurality of record mark lengths of which the shortest mark length is at most 0.4 μm, the recording is made under the following condition:

$M_1/M_0 \geqq 0.9$

wherein M_0 represents a modulation of signals retrieved immediately after the recording, and M_1 represents a modulation of signals retrieved after the recording medium is kept for 1,000 hours under a condition of 80°C and 80% relative humidity after the recording.

7. An optical information recording medium for recording information by a plurality of record mark lengths, which comprises a substrate, and a first protective layer, a phase change recording layer, a second protective layer and a reflective layer, formed on the substrate sequentially from the incident direction of a recording or retrieving laser beam, wherein the shortest mark length is at most 0.5 µm, and a crystal state is an unrecorded or erased state and an amorphous state is a recorded state, wherein the phase change recording layer is made of a thin film having a thickness of from 5 nm to 25 nm and comprising, as a main component, a GeSbTe alloy having a composition represented by a region (except for the boundary lines) defined by four linear lines, i.e. linear line A connecting $(Sb_{0.7}Te_{0.3})$ and Ge, linear line B connecting $(Ge_{0.03}Sb_{0.68}Te_{0.29})$ and $(Sb_{0.95}Ge_{0.05})$, linear line C connecting $(Sb_{0.9}Ge_{0.1})$ and $(Te_{0.9}Ge_{0.1})$ and linear line D connecting $(Sb_{0.8}Te_{0.2})$ and Ge, in the GeSbTe ternary phase diagram, and

the second protective layer has a thickness of from 5 nm to 30 nm.

8. The optical information recording medium according to Claim 7, wherein the recording layer is made of a thin film comprising, as a main component, a GeSbTe alloy having a composition represented by a region (except for the boundary lines) defined by four linear lines, i.e. linear line A connecting ($Sb_{0.7}Te_{0.3}$) and Ge, linear line B′ connecting ($Ge_{0.03}Sb_{0.68}Te_{0.29}$) and ($Sb_{0.9}Ge_{0.1}$), linear line C connecting ($Sb_{0.9}Ge_{0.1}$) and ($Te_{0.9}Ge_{0.1}$) and linear line D connecting ($Sb_{0.8}Te_{0.2}$) and Ge, in the GeSbTe ternary phase diagram.

9. The optical information recording medium according to Claim 7, wherein the recording layer is made of a thin film comprising, as a main component, a $Ge_x(Sb_yTe_{1-y})_{1-x}$ alloy, wherein $0.04 \leqq x < 0.10$ and $0.72 \leqq y < 0.8$.

10. The optical information recording medium according to Claim 7, wherein the recording layer is made of a thin film comprising, as a main component, a $Ge_x(Sb_yTe_{1-y})_{1-x}$ alloy, wherein $0.045 \leqq x \leqq 0.075$ and $0.74 \leqq y < 0.8$.

11. The optical information recording medium according to any one of Claims 7 to 10, wherein the recording layer further contains at least one element selected from the group consisting of O, N and S, and the total content of such elements is from 0.1 atomic % to 5 atomic %.

12. The optical information recording medium according to any one of Claims 7 to 10, wherein the recording layer further contains at least one element selected from the group consisting of V, Nb, Ta, Cr, Co, Pt and Zr, and the

total content of such elements is at most 8 atomic %, and the total content of such elements and Ge is at most 15 atomic %.

13. The optical information recording medium according to any one of Claims 7 to 10, wherein the recording layer further contains at least one element selected from the group consisting of Al, In and Ga, and the total content of such elements is at most 8 atomic %, and the total content of such elements and Ge is at most 15 atomic %.

14. The optical information recording medium according to any one of Claims 7 to 13, wherein the recording layer has a thickness of from 10 nm to 20 nm.

15. The optical information recording medium according to any one of Claims 7 to 14, wherein the second protective layer has a thickness of from 10 nm to 25 nm.

16. The optical information recording medium according to any one of Claims 7 to 15, which is a medium for recording or retrieving information by applying a recording or retrieving laser beam through the substrate, and wherein the first protective layer has a thickness of at least 50 nm.

17. The optical information recording medium according to any one of Claims 7 to 16, wherein the reflective layer has a thickness of from 40 nm to 300 nm and a volume resistivity of from 20 $n\Omega\cdot m$ to 150 $n\Omega\cdot m$.

18. The optical information recording medium according to Claim 17, wherein the reflective layer has a thickness

of from 150 nm to 300 nm and is made of an Al alloy containing from 0.2 atomic % to 2 atomic % of at least one member selected from the group consisting of Ta, Ti, Co, Cr, Si, Sc, Hf, Pd, Pt, Mg, Zr, Mo and Mn.

19. The optical information recording medium according to Claim 17, wherein the reflective layer has a thickness of from 40 nm to 150 nm and is made of a Ag alloy containing from 0.2 atomic % to 5 atomic % of at least one member selected from the group consisting of Ti, V, Ta, Nb, W, Co, Cr, Si, Ge, Sn, Sc, Hf, Pd, Rh, Au, Pt, Mg, Zr, Mo and Mn.

20. The optical information recording medium according to any one of Claims 7 to 16, wherein the reflective layer is a multilayer reflective layer made of a plurality of metal films and at least 50% of the total thickness of the multilayer reflective layer has a volume resistivity of from 20 $n\Omega \cdot m$ to 150 $n\Omega \cdot m$.

21. The optical information recording medium according to any one of Claims 17 to 20, wherein an interfacial layer having a thickness of from 5 nm to 100 nm is formed between the second protective layer and the reflective layer.

22. The optical information recording medium according to Claim 17, wherein an interfacial layer having a thickness of from 1 nm to 100 nm is formed between the second protective layer and the reflective layer, the interfacial layer is made of an Al alloy containing from

0.2 atomic % to 2 atomic % of at least one member selected from the group consisting of Ta, Ti, Co, Cr, Si, Sc, Hf, Pd, Pt, Mg, Zr, Mo and Mn, and the reflective layer is made of Ag or a Ag alloy containing from 0.2 atomic % to 5 atomic % of at least one member selected from the group consisting of Ti, V, Ta, Nb, W, Co, Cr, Si, Ge, Sn, Sc, Hf, Pd, Rh, Au, Pt, Mg, Zr, Mo and Mn.

23. The optical information recording medium according to Claim 22, wherein a layer made of an oxide of the above Al alloy and/or Ag alloy, is present between the interfacial layer and the reflective layer, and the thickness of the oxide layer is from 1 nm to 10 nm.

24. The optical information recording medium according to any one of Claims 7 to 23, wherein the substrate has a groove for recording the information, with a pitch of at most 0.8 µm.

25. The optical information recording medium according to Claim 24, which is a medium for recording data only in the groove, wherein the depth of the groove is within a range of from $\lambda/(20n)$ to $\lambda/(10n)$, where λ is the wavelength of the retrieving laser beam, and n is the refractive index of the substrate at the wavelength.

26. The optical information recording medium according to Claim 25, which is a medium for recording or retrieving data by focusing a laser beam having a wavelength of from 630 to 670 nm on the recording layer through the substrate by an object lens having a

numerical aperture NA of from 0.6 to 0.65, wherein the groove has a groove pitch of from 0.6 to 0.8 μm, a groove depth of from 25 to 40 nm and a groove width of from 0.25 to 0.5 μm, and the groove is wobbling with a period which is from 30 to 40 times the reference clock period T of data, the amplitude of the wobbling (peak-to-peak) being from 40 to 80 nm.

27. The optical information recording medium according to Claim 24, which is a medium for recording data both in the groove and on the land, wherein the groove is present on the substrate, the depth of the groove is from $\lambda/(7n)$ to $\lambda/(5n)$ or from $\lambda/(3.5n)$ to $\lambda/(2.5n)$, where λ is the wavelength of the retrieving laser beam, and n is the refractive index of the substrate at the wavelength, both the groove width GW and the land width LW are from 0.2 μm to 0.4 μm, and the ratio of GW/LW is from 0.8 to 1.2.

28. The optical information recording medium according to any one of Claims 1, 4 and 7, wherein a recording laser beam having an erasing power Pe capable of crystallizing amorphous phase is applied between record marks, and

when the time length of one record mark is represented by nT (wherein T is the reference clock period, and n is an integer of at least 2), the time length nT of the record mark is divided in the order of:

$$\eta_1 T,\ \alpha_1 T,\ \beta_1 T,\ \alpha_2 T,\ \beta_2 T,\ \ldots,$$
$$\alpha_i T,\ \beta_i T,\ \ldots, \alpha_m T,\ \beta_m T,\ \eta_2 T$$

wherein m is a pulse dividing number, and m=n-k, where k is an integer of $0 \leqq k \leqq 2$,

$\Sigma_i(\alpha_i+\beta_i)+\eta_1+\eta_2=n$, η_1 is a real number of $\eta_1 \geqq 0$, η_2 is a real number of $\eta_2 \geqq 0$, provided $0 \leqq \eta_1+\eta_2 \leqq 2.0$,

$\alpha_i (1 \leqq i \leqq m)$ is a real number of $\alpha_i > 0$, $\beta_i (1 \leqq i \leqq m)$ is a real number of $\beta_i > 0$, $\Sigma \alpha_i < 0.5n$,

α_1=0.1 to 1.5, β_1=0.3 to 1.0, β_m=0 to 1.5, α_i=0.1 to 0.8 $(2 \leqq i \leqq m)$, and

when i is $3 \leqq i \leqq m$, $\alpha_i+\beta_{i-1}$ is within a range of from 0.5 to 1.5 and is constant irrespective of i,

a recording laser beam having a writing power Pw of $Pw \geqq Pe$, sufficient to melt the recording layer, is applied within the time of $\alpha_i T$ $(1 \leqq i \leqq m)$, and a recording laser beam having a bias power Pb of $0 < Pb \leqq 0.2Pe$ is applied within the time of $\beta_i T (1 \leqq i \leqq m)$ (provided that within $\beta_m T$, the bias power may be $0 < Pb \leqq Pe$).

29. The optical information recording medium according to Claim 28, whereby when recording or retrieving of data is carried out by focusing a laser beam having a wavelength of from 350 to 680 nm on the recording layer through an object lens having a numerical aperture of from 0.55 to 0.9, the recording is carried out under the following conditions:

m=n-1 or m=n-2,

α_1=0.3 to 1.5,

$\alpha_1 \geqq \alpha_i$=0.2 to 0.8 $(2 \leqq i \leqq m)$,

$\alpha_i+\beta_{i-1}$=1.0 $(3 \leqq i \leqq m)$,

$0 \leqq Pb \leqq 1.5$ (mW),

$0.3 \leqq Pe/Pw \leqq 0.6$.

30. The optical information recording medium according to Claim 28 or 29, whereby when recording or retrieving of data is carried out by focusing a laser beam having a wavelength of from 600 to 680 nm on the recording layer through the substrate by an object lens having a numerical aperture of from 0.55 to 0.65, with the shortest mark length being within a range of from 0.35 to 0.45 μm, the recording is carried out under the following conditions:

n is an integer of from 1 to 14,

$m=n-1$,

Pb is constant irrespective of the linear velocity,

Pe/Pw is changeable depending upon the linear velocity within a range of from 0.4 to 0.6,

(i) within a linear velocity of from 3 to 4 m/s, the reference clock period T is To,

$\alpha_1=0.3$ to 0.8,

$\alpha_1 \geqq \alpha_i=0.2$ to 0.4 and is constant irrespective of i $(2 \leqq i \leqq m)$,

$\alpha_2+\beta_1 \geqq 1.0$

$\alpha_i+\beta_{i-1}=1.0$ $(3 \leqq i \leqq m)$,

$\beta_m= 0.3$ to 1.5, and

a recording laser beam having a writing power Pw1 is irradiated within the time of $\alpha_i T (1 \leqq i \leqq m)$,

(ii) within a linear velocity of from 6 to 8 m/s,

the reference clock period T is To/2,

α'_1=0.3 to 0.8,

$\alpha'_1 \geqq \alpha'_i$=0.3 to 0.5 and is constant irrespective of i ($2 \leqq i \leqq m$),

$\alpha'_i+\beta'_{i-1}$=1.0 ($3 \leqq i \leqq m$),

β'_m= 0 to 1.0, and

a recording laser beam having a writing power Pw2 is irradiated within the time of $\alpha_i T$($1 \leqq i \leqq m$),

wherein $\alpha'_1 > \alpha_i$($2 \leqq i \leqq m$), and $0.8 \leqq Pw1/Pw2 \leqq 1.2$.

31. The optical information recording medium according to Claim 28, having a predetermined record region, whereby recording is carried out by rotating the medium at a constant angular velocity so that the linear velocity at the inner-most diameter of the record region will be from 2 to 4 m/s, and the linear velocity at the outer-most diameter of the record region will be from 6 to 10 m/s, wherein the record region comprises a plurality of radially divided zones, and when recording is carried out by changing the reference clock period T so that the recording density becomes substantially constant depending upon the average linear velocity within each zone, m is made constant irrespective of the zone, and Pb/Pe and/or α_i (where i is at least one of $1 \leqq i \leqq m$) is simply decreased from the outer zone towards the inner zone.

32. The optical information recording medium according to Claim 31, wherein the record region is radially

divided into p zones, and when the inner-most diameter side is referred to as the first zone, the outer-most diameter side is referred to as the p-th zone, and in the q-th zone (wherein q is an integer of $1 \leqq q \leqq p$), the angular velocity is represented by ω_q, the average linear velocity is represented by $\langle V_q \rangle_{ave}$, the maximum linear velocity is represented by $\langle V_q \rangle_{max}$, the minimum linear velocity is represented by $\langle V_q \rangle_{min}$, the reference clock period is represented by T_q, and the time length of the shortest mark is represented by $n_{min}T_q$,

$\langle V_p \rangle_{ave}/\langle V_1 \rangle_{ave}$ is within a range of from 1.2 to 3, and $\langle V_q \rangle_{max}/\langle V_q \rangle_{min}$ is at most 1.5,

(i) within the same zone, ω_q, T_q, α_i, β_i, Pe, Pb and Pw are constant, the physical length $n_{min}T_q\langle V_q \rangle_{ave}$ of the shortest mark is at most 0.5 μm, $T_q\langle V_q \rangle_{ave}$ is substantially constant with respect to all q of $1 \leqq q \leqq p$, and

$m=n-1$ or $m=n-2$,

$\alpha_1=0.3$ to 1.5,

$\alpha_1 \geqq \alpha_i=0.2$ to 0.8 $(2 \leqq i \leqq m)$,

$\alpha_i+\beta_{i-1}=1.0$ $(3 \leqq i \leqq m)$,

$0 \leqq Pb \leqq 1.5$ (mW),

$0.4 \leqq Pe/Pw \leqq 0.6$, and

(ii) for every zone, Pb, Pw, Pe/Pw, $\alpha_i (1 \leqq i \leqq m)$, β_i and β_m are variable, and recording is carried out by simply decreasing at least α_i (i is at least one of $2 \leqq i \leqq m$) from the outer zone towards the inner zone.

33. The optical information recording medium according to Claim 32, wherein $Pw_{max}/Pw_{min} \leqq 1.2$, where Pw_{max} is the maximum value and Pw_{min} is the minimum value of Pw in the record region.

34. The optical information recording medium according to any one of Claims 31 to 33, whereby when recording or retrieving of data is carried out by focusing a laser beam having a wavelength of from 600 to 680 nm on the recording layer through the substrate by an object lens having a numerical aperture NA of from 0.55 to 0.65, the recording is carried out under the following conditions:

the inner-most diameter of the record region is within a range of the radius being from 20 to 25 mm, the radius of the outer-most diameter is within a range of from 55 to 60 mm, and the average linear velocity in the inner-most diameter zone is from 3 to 4 m/s,

when in the q-th zone (wherein q is an integer of $1 \leqq q \leqq p$), the angular velocity is represented by ω_q, the average linear velocity is represented by $\langle V_q \rangle_{ave}$, the maximum linear velocity is represented by $\langle V_q \rangle_{max}$, the minimum linear velocity is represented by $\langle V_q \rangle_{min}$, the reference clock period is represented by T_q, and the time length of the shortest mark is represented by $n_{min}T_q$,

n is an integer of from 1 to 14,

m=n-1,

ω_q, Pb and Pe/Pw are constant irrespective of the zone,

$Tq\langle V_q\rangle_{ave}$ is substantially constant with respect to all q of $1 \leqq q \leqq p$, and

$(\langle V_q\rangle_{max} - \langle V_q\rangle_{min}) / (\langle V_q\rangle_{max} + \langle V_q\rangle_{min}) < 10\%$,

(i) in the first zone,

$\alpha^1{}_1 = 0.3$ to 0.8,

$\alpha^1{}_1 \geqq \alpha^1{}_i = 0.2$ to 0.4 and is constant irrespective of i $(2 \leqq i \leqq m)$,

$\alpha^1{}_2 + \beta^1{}_1 \geqq 1.0$,

$\alpha^1{}_i + \beta^1{}_{i-1} = 1.0$ $(3 \leqq i \leqq m)$,

(ii) in the p-th zone,

$\alpha^p{}_1 = 0.3$ to 0.8,

$\alpha^p{}_1 \geqq \alpha^p{}_i = 0.3$ to 0.5 and is constant irrespective of i $(2 \leqq i \leqq m)$,

$\alpha^p{}_i + \beta^p{}_{i-1} = 1.0$ $(2 \leqq i \leqq m)$, and

(iii) in other zones, $\alpha^1{}_i \leqq \alpha^q{}_i \leqq \alpha^p{}_i$ $(2 \leqq i \leqq m)$, and $\alpha^q{}_1$ is a value between $\alpha^1{}_1$ and $\alpha^p{}_1$.

35. The optical information recording medium according to Claim 34, wherein recording is carried out by adjusting $\alpha^1{}_1 \geqq \alpha^q{}_1 \geqq \alpha^p{}_1$ (provided $\alpha^1{}_1 > \alpha^p{}_1$).

36. The optical information recording medium according to Claim 34 or 35, wherein Pb, Pe/Pw, β_1 and β_m are constant irrespective of the zone, and recording is carried out by changing α_1 and α_i $(2 \leqq i \leqq m)$ depending on the zone.

37. The optical information recording medium according to any one of Claims 34 to 36, wherein numerical values for at least Pe/Pw, Pb, Pw, β_m, $(\alpha^1{}_1, \alpha^p{}_1)$, $(\alpha^1{}_c, \alpha^p{}_c)$

are preliminarily recorded on the substrate by prepits or groove deformation.

38. The optical information recording medium according to any one of Claims 34 to 37, which is an optical information recording medium having an address information preliminarily recorded on the substrate by prepits or groove deformation, wherein the address includes, together with the address information, an information relating to suitable α_1 and α_i ($2 \leqq i \leqq m$).

39. The optical information recording medium according to any one of Claims 1, 4 and 7, wherein a recording laser beam having an erasing power Pe capable of crystallizing amorphous phase is applied between record marks, and

when the time length of one record mark is represented by nT (wherein T is the reference clock period, and n is an integer of at least 2), the time length nT of the record mark is divided in the order of:

$$\eta_1 T,\ \alpha_1 T,\ \beta_1 T,\ \alpha_2 T,\ \beta_2 T,\ \ldots,$$
$$\alpha_i T,\ \beta_i T,\ \ldots, \alpha_m T,\ \beta_m T,\ \eta_2 T$$

wherein m is a pulse dividing number, and m=n-k, where k is an integer of $0 \leqq k \leqq 2$,

$\Sigma_i(\alpha_i+\beta_i)+\eta_1+\eta_2=n$, η_1 is a real number of $\eta_1 \geqq 0$, η_2 is a real number of $\eta_2 \geqq 0$, provided $0 \leqq \eta_1+\eta_2 \leqq 2.0$,

α_i($1 \leqq i \leqq m$) is a real number of $\alpha_i>0$, β_i($1 \leqq i \leqq m$) is a real number of $\beta_i>0$,

α_1=0.1 to 1.5, β_1=0.3 to 1.0, β_m=0 to 1.5, and when

i is $2 \leqq i \leqq m$, α_i is within a range of from 0.1 to 0.8 and is constant irrespective of i, and

when i is $3 \leqq i \leqq m$, $\alpha_i + \beta_{i-1}$ is within a range of from 0.5 to 1.5 and is constant irrespective of i,

a recording laser beam having a writing power Pw of Pw>Pe, sufficient to melt the recording layer, is applied within the time of $\alpha_i T$ ($1 \leqq i \leqq m$), and a recording laser beam having a bias power Pb of $0 < Pb \leqq 0.2Pe$ is applied within the time of $\beta_i T$($1 \leqq i \leqq m$) (provided that within $\beta_m T$, the bias power may be $0 < Pb \leqq Pe$), and

while maintaining m, $\alpha_i + \beta_{i-1}$($3 \leqq i \leqq m$), $\alpha_1 T$ and $\alpha_i T$($2 \leqq i \leqq m$) to be constant irrespective of the linear velocity, β_m is changed so that it simply increases as the linear velocity is small.

40. The optical information recording medium according to Claim 39 for recording under the following conditions:

$Pw_{max}/Pw_{min} \leqq 1.2$,

$Pe/Pw = 0.4$ to 0.6,

$0 \leqq Pb \leqq 1.5$ (mW)

where Pw_{max} is the maximum recording power and Pw_{min} is the minimum recording power, at each recording linear velocity.

41. The optical information recording medium according to Claim 40 for recording under a condition of $\Sigma \alpha_i < 0.5n$ at a recording linear velocity of at most 5 m/s.

42. The optical information recording medium according to Claim 40 or 41 for recording under a condition such

that when β_m at the maximum recording linear velocity is represented by β^H_m and β_m at the minimum recording linear velocity is represented by β^L_m, β_m at other recording linear velocities is a value between β^L_m and β^H_m, and Pb and Pe/Pw are constant irrespective of the recording linear velocity.

43. The optical information recording medium according to Claim 39 or 40 for recording under a condition such that β_m is constant irrespective of the recording linear velocity.

44. The optical information recording medium according to Claim 42, wherein numerical values for at least the Pe/Pw ratio, Pb, Pw, α_1T, α_iT ($2 \leqq i \leqq m$) and (β^L_m, β^H_m) are preliminarily recorded on the substrate by prepits or groove deformation.

45. The optical information recording medium according to any one of Claims 1, 4 and 7, which is an optical information recording medium having a predetermined record region, the record region being divided into p zones having radially equal widths and designed to record information by a plurality of mark lengths, by rotating the medium at a constant angular velocity irrespective of the radial position, wherein on the substrate, a groove having a predetermined groove-wobbling signal, is formed, so that the reference period of the groove-wobbling signal varies for every zone, and when in the q-th zone (provided that q is an integer of $1 \leqq q \leqq p$), the average

linear velocity is represented by $\langle V_q\rangle_{ave}$, the maximum linear velocity is represented by $\langle V_q\rangle_{max}$, the minimum linear velocity is represented by $\langle V_q\rangle_{min}$ and the reference period of the groove-wobbling signal is represented by Tw_q,

$\langle V_q\rangle_{ave}Tw_q$ is constant, and

$(\langle V_q\rangle_{max}-\langle V_q\rangle_{min})/(\langle V_q\rangle_{max}+\langle V_q\rangle_{min})<1\%$.

46. The optical information recording medium according to Claim 45, wherein one revolution of the above groove is taken as one zone, the groove is wobbling with a constant period irrespective of the zone, and the following relation is approximately satisfied:

$2\pi\cdot TP=a\cdot Tw_0\cdot v_0$

where TP is the groove pitch, Tw_0 is the wobbling period, and a is a natural number.

47. The optical information recording medium according to any one of Claims 1, 4 and 7, which is an optical information recording medium having a predetermined record region, the record region being divided into p zones (provided that p is an integer of at least 200) having radially equal widths, and designed to record information by a plurality of mark lengths, by rotating the medium at a constant angular velocity irrespective of the radial position, wherein on the substrate, a groove having a predetermined groove-wobbling signal, is formed, so that the reference period of the groove-wobbling signal varies for every zone, and $\langle V_q\rangle_{ave}Tw_q$ is constant,

where $\langle V_q\rangle_{ave}$ is the average linear velocity, and Tw_q is the reference period of the groove-wobbling signal.

48. The optical information recording medium according to Claim 47, wherein the inner-most diameter of the above record region is within a range of the radius being from 20 to 25 mm, and the outer-most diameter is within a range of the radius being from 55 to 60 mm.

49. An optical recording method for an optical information recording medium, which comprises recording information on the optical information recording medium as defined in any one of Claims 1, 4 and 7, wherein a recording laser beam having an erasing power Pe capable of crystallizing amorphous phase is applied between record marks, and

when the time length of one record mark is represented by nT (wherein T is the reference clock period, and n is an integer of at least 2), the time length nT of the record mark is divided in the order of:

$$\eta_1T,\ \alpha_1T,\ \beta_1T,\ \alpha_2T,\ \beta_2T,\ \ldots,$$

$$\alpha_iT,\ \beta_iT,\ \ldots,\alpha_mT,\ \beta_mT,\ \eta_2T$$

wherein m is a pulse dividing number, and m=n-k, where k is an integer of $0\leqq k\leqq 2$,

$\Sigma_i(\alpha_i+\beta_i)+\eta_1+\eta_2=n$, η_1 is a real number of $\eta_1\geqq 0$, η_2 is a real number of $\eta_2\geqq 0$, provided $0\leqq\eta_1+\eta_2\leqq 2.0$,

$\alpha_i(1\leqq i\leqq m)$ is a real number of $\alpha_i>0$, $\beta_i(1\leqq i\leqq m)$ is a real number of $\beta_i>0$, $\Sigma\alpha_i<0.5n$,

α_1=0.1 to 1.5, β_1=0.3 to 1.0, β_m=0 to 1.5, α_i=0.1 to

0.8 ($2 \leqq i \leqq m$), and

when i is $3 \leqq i \leqq m$, $\alpha_i + \beta_{i-1}$ is within a range of from 0.5 to 1.5 and is constant irrespective of i,

a recording laser beam having a writing power Pw of $Pw \geqq Pe$, sufficient to melt the recording layer, is applied within the time of $\alpha_i T$ ($1 \leqq i \leqq m$), and a recording laser beam having a bias power Pb of $0 < Pb \leqq 0.2Pe$ is applied within the time of $\beta_i T$ ($1 \leqq i \leqq m$) (provided that within $\beta_m T$, the bias power may be $0 < Pb \leqq Pe$).

50. The optical recording method according to Claim 49, wherein recording or retrieving of data is carried out by focusing a laser beam having a wavelength of from 350 to 680 nm on the recording layer through an object lens having a numerical aperture NA of from 0.55 to 0.9, and wherein:

$m = n-1$ or $m = n-2$,

$\alpha_1 = 0.3$ to 1.5,

$\alpha_1 \geqq \alpha_i = 0.2$ to 0.8 ($2 \leqq i \leqq m$),

$\alpha_i + \beta_{i-1} = 1.0$ ($3 \leqq i \leqq m$),

$0 \leqq Pb \leqq 1.5$ (mW),

$0.3 \leqq Pe/Pw \leqq 0.6$.

51. The optical recording method according to Claim 49 or 50, wherein recording or retrieving of data is carried out by focusing a laser beam having a wavelength of from 600 to 680 nm on the recording layer through the substrate by an object lens having a numerical aperture NA of from 0.55 to 0.65, with the shortest mark length

being within a range of from 0.35 to 0.45 µm, and wherein:

n is an integer of from 1 to 14,

$m=n-1$,

Pb is constant irrespective of the linear velocity,

Pe/Pw is changeable depending upon the linear velocity within a range of from 0.4 to 0.6,

(i) within a linear velocity of from 3 to 4 m/s, the reference clock period T is To,

$\alpha_1=0.3$ to 0.8,

$\alpha_1 \geqq \alpha_i=0.2$ to 0.4 and is constant irrespective of i $(2 \leqq i \leqq m)$,

$\alpha_2+\beta_1 \geqq 1.0$

$\alpha_i+\beta_{i-1}=1.0$ $(3 \leqq i \leqq m)$,

$\beta_m= 0.3$ to 1.5, and

a recording laser beam having a writing power Pw1 is irradiated within the time of $\alpha_i T (1 \leqq i \leqq m)$,

(ii) within a linear velocity of from 6 to 8 m/s, the reference clock period T is To/2,

$\alpha'_1=0.3$ to 0.8,

$\alpha'_1 \geqq \alpha'_i=0.3$ to 0.5 and is constant irrespective of i $(2 \leqq i \leqq m)$,

$\alpha'_i+\beta'_{i-1}=1.0$ $(3 \leqq i \leqq m)$,

$\beta'_m=$ 0 to 1.0, and

a recording laser beam having a writing power Pw2 is irradiated within the time of $\alpha_i T (1 \leqq i \leqq m)$,

wherein $\alpha'_i > \alpha_i (2 \leqq i \leqq m)$, and $0.8 \leqq Pw1/Pw2 \leqq 1.2$.

52. The optical recording method according to Claim 49, which is a method for recording information by a plurality of mark lengths by rotating the medium having a predetermined record region, at a constant angular velocity, wherein the medium is rotated so that the linear velocity at the inner-most diameter of the record region will be from 2 to 4 m/s, and the linear velocity at the outer-most diameter of the record region will be from 6 to 10 m/s, wherein the record region comprises a plurality of radially divided zones, and recording is carried out by changing the reference clock period T so that the recording density becomes substantially constant depending upon the average linear velocity within each zone, m is made constant irrespective of the zone, and Pb/Pe and/or α_i (i is at least one of $1 \leqq i \leqq m$) is simply decreased from the outer zone towards the inner zone.

53. The optical recording method according to Claim 52, wherein the record region is radially divided into p zones, and when the inner-most diameter side is referred to as the first zone, the outer-most diameter side is referred to as the p-th zone, and in the q-th zone (wherein q is an integer of $1 \leqq q \leqq p$), the angular velocity is represented by ω_q, the average linear velocity is represented by $\langle V_q \rangle_{ave}$, the maximum linear velocity is represented by $\langle V_q \rangle_{max}$, the minimum linear velocity is represented by $\langle V_q \rangle_{min}$, the reference clock period is represented by T_q, and the time length of the

shortest mark is represented by $n_{min}T_q$,

$<V_p>_{ave}/<V_1>_{ave}$ is within a range of from 1.2 to 3, and $<V_q>_{max}/<V_q>_{min}$ is at most 1.5,

(i) within the same zone, ω_q, T_q, α_i, β_i, Pe, Pb and Pw are constant, the physical length $n_{min}T_q<V_q>_{ave}$ of the shortest mark is at most 0.5 µm, $T_q<V_q>_{ave}$ is substantially constant with respect to all q of $1 \leqq q \leqq p$, and

$m=n-1$ or $m=n-2$,

$\alpha_1=0.3$ to 1.5,

$\alpha_1 \geqq \alpha_i=0.2$ to 0.8 $(2 \leqq i \leqq m)$,

$\alpha_i+\beta_{i-1}=1.0$ $(3 \leqq i \leqq m)$,

$0 \leqq Pb \leqq 1.5$ (mW),

$0.4 \leqq Pe/Pw \leqq 0.6$, and

(ii) in each zone, Pb, Pw, Pe/Pw, $\alpha_i (1 \leqq i \leqq m)$, β_1 and β_m are variable, and at least α_i (i is at least one of $2 \leqq i \leqq m$) simply decreases from the outer zone towards the inner zone.

54. The optical recording method according to Claim 53, wherein $Pw_{max}/Pw_{min} \leqq 1.2$, where Pw_{max} is the maximum value and Pw_{min} is the minimum value of Pw in the record region.

55. The optical recording method according to any one of Claims 52 to 54, wherein recording or retrieving of data is carried out by focusing a laser beam having a wavelength of from 600 to 680 nm on the recording layer through the substrate by an object lens having a numerical aperture NA of from 0.55 to 0.65, and wherein:

the inner-most diameter of the record region is within a range of the radius being from 20 to 25 mm, the radius of the outer-most diameter is within a range of from 55 to 60 mm, and the average linear velocity in the inner-most diameter zone is from 3 to 4 m/s,

when in the q-th zone (wherein q is an integer of $1 \leqq q \leqq p$), the angular velocity is represented by ω_q, the average linear velocity is represented by $\langle V_q \rangle_{ave}$, the maximum linear velocity is represented by $\langle V_q \rangle_{max}$, the minimum linear velocity is represented by $\langle V_q \rangle_{min}$, the reference clock period is represented by T_q, and the time length of the shortest mark is represented by $n_{min}T_q$,

n is an integer of from 1 to 14,

$m=n-1$,

ω_q, Pb and Pe/Pw are constant irrespective of the zone,

$Tq\langle V_q \rangle_{ave}$ is substantially constant with respect to all q of $1 \leqq q \leqq p$, and

$(\langle V_q \rangle_{max}-\langle V_q \rangle_{min})/(\langle V_q \rangle_{max}+\langle V_q \rangle_{min})<10\%$,

(i) in the first zone,

$\alpha^1_1=0.3$ to 0.8,

$\alpha^1_1 \geqq \alpha^1_i=0.2$ to 0.4 and is constant irrespective of i $(2 \leqq i \leqq m)$,

$\alpha^1_2+\beta^1_1 \geqq 1.0$,

$\alpha^1_i+\beta^1_{i-1}=1.0$ $(3 \leqq i \leqq m)$,

(ii) in the p-th zone,

$\alpha^p_1=0.3$ to 0.8,

$\alpha^{p}_{1} \geqq \alpha^{p}_{i}$=0.3 to 0.5 and is constant irrespective of i ($2 \leqq i \leqq m$),

$\alpha^{p}_{i} + \beta^{p}_{i-1} \geqq 1.0$ ($2 \leqq i \leqq m$), and

(iii) in other zones, $\alpha^{1}_{i} \leqq \alpha^{q}_{i} \leqq \alpha^{p}_{i}$ ($2 \leqq i \leqq m$), and α^{q}_{1} is a value between α^{1}_{1} and α^{p}_{1}.

56. The optical recording method according to Claim 55, wherein $\alpha^{1}_{1} \geqq \alpha^{q}_{1} \geqq \alpha^{p}_{1}$ (provided $\alpha^{1}_{1} > \alpha^{p}_{1}$).

57. The optical recording method according to Claim 55 or 56, wherein Pb, Pe/Pw, β_1 and β_m are constant irrespective of the zone, and only α_1 and α_i ($2 \leqq i \leqq m$) are changed depending upon the zone.

58. An optical recording method for an optical information recording medium, which comprises recording information on the optical information recording medium as defined in any one of Claims 1, 4 and 7, wherein a recording laser beam having an erasing power Pe capable of crystallizing amorphous phase is applied between record marks, and

when the time length of one record mark is represented by nT (wherein T is the reference clock period, and n is an integer of at least 2), the time length nT of the record mark is divided in the order of:

$$\eta_1 T,\ \alpha_1 T,\ \beta_1 T,\ \alpha_2 T,\ \beta_2 T,\ \ldots,$$

$$\alpha_i T,\ \beta_i T,\ \ldots,\ \alpha_m T,\ \beta_m T,\ \eta_2 T$$

wherein m is a pulse dividing number, and m=n-k, where k is an integer of $0 \leqq k \leqq 2$,

$\Sigma_i(\alpha_i + \beta_i) + \eta_1 + \eta_2 = n$, η_1 is a real number of $\eta_1 \geqq 0$, η_2

is a real number of $\eta_2 \geqq 0$, provided $0 \leqq \eta_1 + \eta_2 \leqq 2.0$,

$\alpha_i (1 \leqq i \leqq m)$ is a real number of $\alpha_i > 0$, $\beta_i (1 \leqq i \leqq m)$ is a real number of $\beta_i > 0$,

$\alpha_1 = 0.1$ to 1.5, $\beta_1 = 0.3$ to 1.0, $\beta_m = 0$ to 1.5, and when i is $2 \leqq i \leqq m$, α_i is within a range of from 0.1 to 0.8 and is constant irrespective of i, and

when i is $3 \leqq i \leqq m$, $\alpha_i + \beta_{i-1}$ is within a range of from 0.5 to 1.5 and is constant irrespective of i,

a recording laser beam having a writing power Pw of Pw>Pe, sufficient to melt the recording layer, is applied within the time of $\alpha_i T$ $(1 \leqq i \leqq m)$, and a recording laser beam having a bias power Pb of $0 < Pb \leqq 0.2Pe$ is applied within the time of $\beta_i T (1 \leqq i \leqq m)$ (provided that within $\beta_m T$, the bias power may be $0 < Pb \leqq Pe$), and

while maintaining m, $\alpha_i + \beta_{i-1} (3 \leqq i \leqq m)$, $\alpha_1 T$ and $\alpha_i T$ $(2 \leqq i \leqq m)$ to be constant irrespective of the linear velocity, β_m is changed so that it simply increases as the linear velocity is small.

59. The optical recording method according to Claim 58 for recording under the following conditions:

$Pw_{max}/Pw_{min} \leqq 1.2$,

$Pe/Pw = 0.4$ to 0.6,

$0 \leqq Pb \leqq 1.5$ (mW)

where Pw_{max} is the maximum recording power and Pw_{min} is the minimum recording power, at each recording linear velocity.

60. The optical recording method according to Claim 59

for recording under a condition of $\Sigma \alpha_i < 0.5n$ at a recording linear velocity of at most 5 m/s.

61. The optical recording method according to Claim 59 for recording under a condition such that when β_m at the maximum recording linear velocity is represented by β^H_m and β_m at the minimum recording linear velocity is represented by β^L_m, β_m at other recording linear velocities is a value between β^L_m and β^H_m, and Pb and the Pe/Pw ratio are constant irrespective of the recording linear velocity.

62. The optical recording method according to any one of Claims 58 to 60 for recording under a condition such that β_m is constant irrespective of the recording linear velocity.

63. The optical recording method according to any one of Claims 58 to 62, which is a method for recording information by a plurality of mark lengths by rotating an optical information recording medium having a predetermined record region, wherein the record region is divided into a plurality of zones in the radial direction, and within each zone, recording is carried out at a constant linear velocity, the ratio of the recording linear velocity V_{out} at the outer-most diameter zone to the recording linear velocity V_{in} at the inner-most diameter zone, i.e. V_{out}/V_{in}, is from 1.2 to 2, and β_m is changed depending upon the linear velocity in each zone.

64. The optical recording method according to Claim 49,

which is a method for recording information by a plurality of mark lengths by rotating an optical information recording medium having a predetermined record region, wherein the record region is divided into a plurality of zones in the radial direction, and in each zone, recording is carried out at a constant linear velocity,

the ratio of the recording linear velocity V_{out} in the outer-most diameter zone to the recording linear velocity V_{in} in the inner-most diameter zone, i.e. V_{out}/V_{in}, is from 1.2 to 2,

α_i=0.3 to 0.6 ($2 \leqq i \leqq m$), and β_m=0 to 1.5, and

m, $\alpha_i+\beta_{i-1}$($3 \leqq i \leqq m$), α_1T, Pe/Pw and Pb are constant irrespective of the linear velocity, and α_i and/or β_m is changed depending upon the linear velocity.

65. An optical recording method, which comprises recording information on the optical information recording medium as defined in any one of Claims 45 to 48, wherein the reference clock period T_q is generated as a multiple or a divisor of the reference period Tw_q of the groove wobbling in each zone.